

AI Green Ports & Climate Resilience

Port Automation Evolution of Intelligent Technology Vs Actual Operation of Port Equipment



Due to the deepening levels of port automation and intelligence the degree of equipment automation and the complexity of maintenance operations have increased substantially. Consequently the evolution of intelligent technology has led to significant shifts in the types and quantities of issues encountered during the actual operation of equipment compared to historical contexts. The prevailing understanding of equipment maintenance systems might restrict ports' capacity to handle emergencies and exacerbate operational risks. Multiple challenges remain in applying intelligent technologies such as data integration, fault tracking, real-time diagnosis and enhancing data fusion capabilities which should elevate the intelligence of port equipment. As pivotal transportation hubs ports substantially influence global logistics efficiency, economic development and reliable operation of port equipment being vital to ensuring smooth cargo handling and logistical efficiency. The health status of various port equipment including cranes, conveyors and automated stacking systems, directly affects port operational efficiency and safety and poor conditions of port equipment can obstruct or even disrupt port operations . Intelligent maintenance combines sensor networks, data analysis and Internet of Things technology to monitor real-time equipment status and predict failures.

International Maritime Organization & Smart Ports

The United Nations International Maritime Organization (IMO) currently does not have a unified and precise definition of smart ports apart from advocating integrated with environmental protection and a green perspective to become a smart port. The Smart Port Index (SPI) is generally based on four key performance indicators (KPI) including operations, environment, energy, safety and security. Each Smart Port model incorporates identification of an optimal adoption strategy on smart technology and analysis of the impact of network externality on the port's pricing and adoption decisions. Digitized port management reflects a process of transformation and globalized social and socioeconomic evolution that must contribute to the era of the green transition.

Port Digitization

The digitization process roughly involves the first stage (1980' s) which is still in the stage of digitalizing information. In order to meet the high-efficiency information flow required for maritime transportation the emergence of electronic data inflow (EDI) technology has gradually made important trade related documents and transportation information electronically digitized. The second stage (1990~2010) witnessed the digital development of technology, introduced positioning and identification technology and integrated the awareness of environmental protection such as the Truck Reservation System (TAS) and Ship Automatic Identification System (AIS). This stage is to achieve an essential foundation for terminal automation which will be laid in the future. The third stage (2010-present) regards the port as a maritime logistics center that combines roads and railways and emphasises the flow of information in the port area and the use of data and telecommunications and the installation of sensors to promote two way communication between machines which has gradually formed an automated way of working. The digital development of the port has moved from paperless to the introduction of automation and then evolved to the application of digital. Each upgrade stage is based on the power of digital technology. Digitization is the driving force for the growth of ports and port digitization refers to the evolution of port operations from physical to virtual status. Digitization no doubt can improve port performance, reduce costs and increase safety and security.

Investment in Port Digitalization

Port digitalization is still in its infancy stage on account of high investment costs. According to a survey about 10 billion U.S. dollars are currently invested in constructing digital equipment in the port yielding reduction in operating cost as low as 25 % to 55 % in actual operations and decreased productivity by 7 % to 15 %. Such low reduction in operating cost is attributed to the long-term integration of new and old technologies, training of Dockers on new technologies as need for more standardization of digital platform systems delay port's digitalization plans.

Limitations of Digital Technology

Digital technology can significantly solve the problem of workforce shortage and promote and maintain a ports operation while protecting the health and safety of port and related employees. Yet the application of digital technology research in ports is far less than that of other industries despite being capable of assisting stakeholders in the maritime supply chain to adopt feasible port digitalization strategies to improve port operation efficiency and climate change resilience. Challenges persist such as data privacy, algorithmic bias and the need for standardized regulations which will eventually need to be addressed.



Credit; the Maritime Executive

The International Longshoremen's Association and the United States Maritime Alliance (USMX) representing terminal operators are in intense negotiations for a new master contract. A strike closed ports from Maine to Florida and along the U.S. Gulf Coast. Tensions loomed as the US East Coast Port Union went on a strike over automation threats accusing port authorities of introducing job-cutting automation covering 45,000 workers and rejecting any automation to protect union jobs. The USMX advocates usage of digital technology for safety, efficiency and future supply chain demands yet tensions remain high over job security vs. modernization.

Ports Regional Importance Bolstered by AI

Ports importance for logistics, supply chain management and the economy at regional, national and international levels cannot be understated as ports facilitate access to key resources through transport and services, including energy, health, labour aspects, passenger mobility and accessibility. This is particularly important for inland or island regions. Ports act as gateways and centres of economic and social interaction, promoting, regional economic development and social inclusion. Artificial Intelligence (AI) has become a critical enabler in enhancing the efficiency and competitiveness of port operations as integrating AI technologies and Internet of Things, sensor networks, cloud computing and AI based decision analysis leads to intelligent cargo handling, ship scheduling, security monitoring and port management optimization. Future port operations will benefit from effective human-

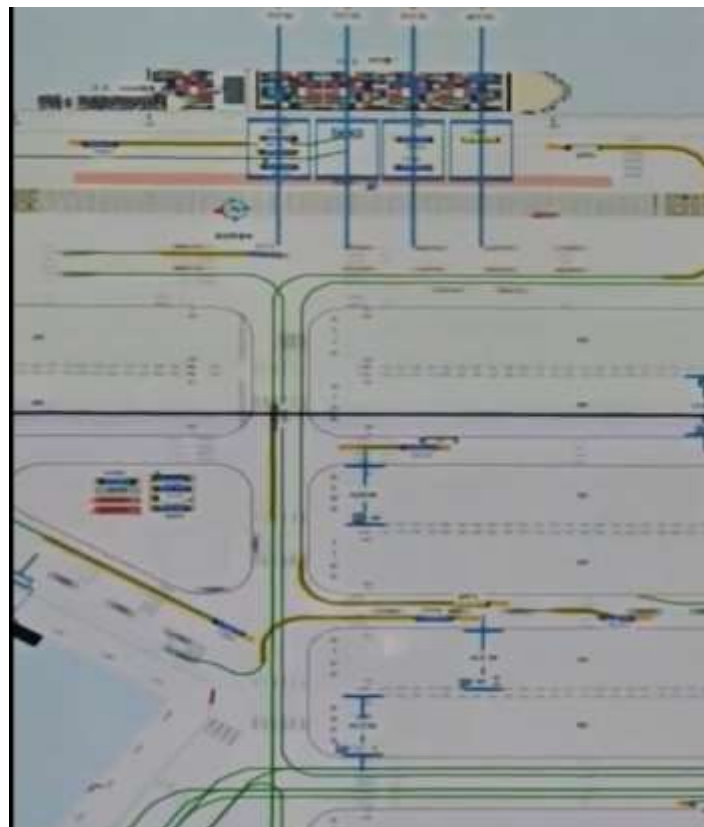
machine collaboration and continuous advancements in AI technologies, ensuring sustainable and competitive growth in the maritime industry.

Port city refers to a city of special type that has a port with the function of water and land transportation hub and the port is at the core of a city's economic development. Port and city, located in a limited space, share resources and are closely linked economically and coordinated development has traditionally and comprehensively strengthened the commercial activities in port cities while realizing the region's sustainable development with the port taking the leading role. Integrating capital, technology, logistics and information the port is the gateway and economic growth pole of the hinterland city and the regional economy towards the goal of achieving balanced regional development and upgrading industrial structure.



Chinese Model as Recent AI Port

With the deepening development of globalization the coastal areas of developing countries are becoming carriers of global industrial transfer. The China Port Yearbook shares that from 2001 to 2017 the cargo and container throughput of Chinese ports increased phenomenally from 1.5 billion tons and 27 million TEU to 12.6 billion tons and 240 million TEU, with average annual growth rates of 14.2 % and 14.6 %, respectively . Chinese ports are afflicted from a capacity surplus and serious homogenization concerns intensifying the vicious competition among ports causing excessive waste of port resources. This perhaps compelled the CPC Central Committee and the State Council to approve the “Overall Layout Plan for Digital China Construction” in the year 2023 emphasizing the comprehensive improvement of the integrity, systematization and



coordination of digital China construction, promoting the deep integration of the digital economy and the real economy, driving the reform of production, life and governance with digitization. A prime showpiece of Chinese port digital development is Guangdong province ranked top in China in terms of digital economy scale with the digital economy accounting for more than 50% of the Gross Domestic Product (GDP) in the year 2021. A strong province in

multimodal transportation the port layout plan of Guangdong Province (2021–2035) is oriented towards building a world standard port in China and establishing a “one core and two poles” development pattern with the Pearl River Delta as the core and the eastern and western areas as the development poles.

Spatial Effects of Digital Economy on Port City

Growth in one region’s digital economy and port industry may have a cascading or spillover impact on the development of other regions and impact of digital economy on port city coordinated development is likely to have non-linear characteristics and spatial spillover effects on neighboring regions considering interaction of port indicators , hinterland economic development , port scale , port freight infrastructure , port operation and econometrics to explore the interaction mechanism of a port city .

Carbon Emissions Smart Policies & Chinese Policy

China has focused on constructing smart ports as an innovative segment of its huge shipping operations. As a significant port country it boasts over 2520 berths weighing ten thousand plus tons and has long accounted for over 40 % of the world’s top 20 ports in terms of container throughput and such high cargo throughput volume means that energy consumption in ports accounts for a significant proportion of the entire transportation industry. According to the International Energy Agency (2024) global carbon emissions or carbon footprint of China reached 37.4 billion tons in the year 2023. China’s national strategic goal is reaching peak carbon emissions by 2030 and peak carbon neutrality emissions by 2060. Considering the growing volume of seaborne trade worldwide ports require smart policies to address high carbon emissions and being a major shipping nation China is committed to reducing port carbon emissions .A study of 39 major ports in China revealed that smart policies are being implemented. The number of port berths, length of wharves and container throughput are important mechanisms through which smart port policies may influence carbon emission efficiency. This research enriches carbon emission efficiency literature offering insights for developing countries on reducing emissions and achieving carbon neutrality and provides a basis for China’s smart port construction. Construction of smart ports can reduce logistics costs, optimize operation processes and improve energy utilization efficiency, allowing ports to fully automate and efficiently complete the loading and unloading of cargo and directing ships to and from the port while reducing carbon emissions. Specific port related operational benefits of digital-based smart technology systems include reduced delivery times, improved information storage and internal communications, data on cargo conditions or infrastructure being available in real time and enhanced customer experience. Port somatization has driven automated applications such as container terminal operations, automated guided vehicles, vessel intelligence, autonomous vessel driving technology and intelligent vessel management systems thereby promoting intelligent operational management of terminal operations.

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